THE CAUSAL RELATIONSHIP BETWEEN ENERGY CONSUMPTION AND GDP
The Case of Indonesia

Lincolin Arsyad

Artikel ini menganalisis hubungan kausal antara konsumsi energi agregat dengan produk domestik bruto (PDB) Indonesia. Dengan menggunakan model kausalitas dari Granger dan Sim, ditemukan bahwa PDB mempengaruhi tingkat konsumsi energi agregat tetapi konsumsi energi agregat tidak mempengaruhi PDB. Dengan kata lain, walaupun tingkat kegiatan ekonomi mempengaruhi tingkat konsumsi energi agregat tetapi tingkat konsumsi energi agregat tidak mempengaruhi tingkat kegiatan ekonomi. Hal tersebut menyiratkan bahwa terdapat kemungkinan untuk menurunkan jumlah energi yang dibutuhkan untuk menghasilkan tingkat PDB tertentu tanpa kenaikan penggunaan masukan-masukan lain. Oleh karena itu, program konservasi energi merupakan suatu alat kebijakan yang laik untuk membuat perekonomian Indonesia lebih kompetitif melalui penurunan biaya produksi.

Introduction

The important role of energy in an economy has been increasingly recognized by economists since the world economic recessions following the Arab oil embargo in 1973. The relationships between energy consumption and employment and gross national product have been the subject of intense research and heated debate. In Indonesia the studies concerning the role of energy sector in economic growth can be classified into two groups (Hadi Soesastro, 1985). As an oil exporter, the economy of Indonesia has been influenced greatly by the rising oil price in the international market in the 1970s. As prices increased, foreign exchange rose and so did government revenue from the oil taxes.

The second group of studies analyzes the relationship between energy input and economic development, and concerns about aggregative relationship between energy input and economic output (GNP, GDP) or with specific policy problems such as energy pricing and conservation policy, which affect the pattern of energy consumption and production process in the economy.

The purpose of this study is to analyze the relationship between gross energy input and economic development and more specifically is to examine the causality between energy consumption and GDP in Indonesia.

The Energy-Economy Interactions

The aggregate relationship between the energy and an economy commonly analyzed by several measures. The simplest measure is the energy/GDP ratio (energy intensity) which is the amount of energy used to produce one unit of output. Another measure is the relation between the percentage increase in energy use and the percentage increase of output (GDP) or national income which is usually called income elasticity of consumption.

Some studies indicate that the normal view of energy-GDP ratio always rise in low-income countries since nearly all the major economic changes associated with development -including increased industrialization and urbanization, and greater demands for transport with higher incomes- point towards an increased energy intensity. The more moderate increase is in the semi industrialized countries. Here structural change is less rapid and the substitution process less pronounced, while urbanization has already reached a fairly high level. In industrialized countries, energy intensity declines both because the economic structure is changing towards a low energy-intensive service sector and also because in many areas there is a growing application of energy-saving technologies (Allen, 1976; Khazzoom, 1976, Hitch, 1978; Long, 1978).

Based on their study, Elias & Grabik (1980) conclude that the energy-GDP ratio depends on the stages of economic development, climatic condition, structure of energy consumption pattern, energy supply, and in overall economic conditions inherent with political structures.

A study of Zilberfarb-Adams (1981) indicates that the relationship between energy and GDP in developing countries has been stable over time. The 'energy crisis' has not upset this relationship. There is a possibility that there is a price effect, though unfortunately, it does not show so quickly in the data due to a long-term adjustment process. If this is the case, then the high and constant elasticities indicate a prognosis for the developing countries which is very bleak. In the short and medium run, higher energy costs will drive down the rate of economic growth.

This study has also found that the income elasticity of energy consumption for developing countries is about 1.35. A high income elasticity may reflect an increasing industrialization process in developing countries. This also implies that energy consumption would have to rise faster than GDP to support future economic growth in developing countries. It would imply that energy demand reduction due to price increase would seriously curtail output. This, however, has validity in the short run when there are sudden absolute shortages of energy input. But in the long run, a physical plant structure can be geared to a low and more efficient use of energy.

In Indonesia, the energy-GDP ratio (energy intensity) increased between 1960 and 1965 and leveled off between 1965 and 1969 (Hadi Soesastro, 1985). Since 1969, the ratio increased by 6.2 percent per year. Between 1979 and 1983 the ratio was almost constant. In the period of 1960-65 the ratio increased by 5.5

percent per year while per capita income was stagnant and industrialization process declined. This change is indee the inferior comparied with the change in the later period. However, the comparison is not conclusive because the energy-GDP ratio rises less rapidly than per capita income and the industrialization process.

The energy consumption analysis should be used to evaluate the change of energy intensity in the above periods. The study also indicates that between 1960-69, 43.4 percent of the increase in energy consumption was caused by economic growth and 41.6 percent was caused by on increasing energy intensity. While in the period of 1969-83, 43.6 percent of the increases in energy consumption was caused by economic growth and only 21.2 percent was caused by an increasing energy intensity.

In other words, the results imply that there is a low-efficiency of energy use in Indonesia. The increase of energy consumption is caused more by the increase of energy intensity than by the increase of economic growth. This low-efficiency is also indicated by the decreasing energy GDP ratio that reflects the efficiency of energy use.

Literature Review

Earlier study in this area published in 1970s and 1980s whuch include studies by Kraft and Kraft (1978), Akarca and Long (1979 and 1980), Yu and Hwang (1984), and Yu and Choi (1985) have analyzed the causal relationship between gross energy consumption and employment and GNP.

Using the Sims' technique, Kraft and Kraft (1978) found the presence of a strong relationship between gross energy input (GEI) and gross national product (GNP) and unidirectional causality running only from GNP to GEI in the period of 1947 to 1974 in the United States. Their results imply that energy conservation is a feasible policy option without impairing economic activity because while the level of economic activity may influence the consumption of energy, the level of gross energy consumption has no causal influence on economic activity.

However, the unidirectional causality from GNP to energy was questioned by Akarca and Long. By shortening the data sample of Kraft and Kraft by two years, Akarca and Long argue that the results obtained by Kraft and Kraft appear to be spurious and to arise solely from the inclusion of two additional years in the data sample.

In another paper Akarca and Long examined the relation between US domestic energy consumption and total employment for the period 1973-1978. Using sophisticated Box-Jenkins type time-series procedures and Granger's criterion, they established a unidirectional causality running from energy to employment. Furthermore, the relationship between the response of employment to change the energy input is negative. This is an interesting result in its own right, because it implies that total employment would slightly increase as a result of energy conservation.

In 1984 Yu and Hwang reexamined the causality between GNP and energy consumption (EC) by using updated US data for the period 1947-1979. As a secondary contribution, they investigated the causal relationship between energy consumption and employment.

Applying Sims' technique they found no causal relationship between GNP and energy consumption. This finding is supportive of Akarca and Long's argument that the causal order suggested by Kraft and Kraft from GNP to energy is a spurious one. They also observed a slightly unidirectional causality running from employment to energy, which is inconsistent with the findings of Akarca and Long.

In 1985 the causal relationship between energy and GNP were again examined from an international perspective by Yu and Choi as an extension of their previous analysis. They examined the relationships in five countries in various stages of development for the purpose of comparison and generalization. A major finding is that the relationship between energy consumption and GNP varies among countries and the results of causality tests are fairly sensitive to samples. They found no causal relationships between total energy consumption and GNP in the United States, the United Kingdom, and Poland. While causal relationship from GNP to total energy consumption was detected for South Korea and causal linkage from total energy consumption to GNP was discerned for the Philippines.

Methodology and Model

Causation is an important concept in economics and in science in general. Causal relations are often difficult to define, and different definitions have been offered. Once a certain definition has been accepted, there is a difficult problem of identifying a causal relation in empirical work. One useful definition of causation in econometrics has been suggested by Granger (1969). The Granger definition exploits time-series relationship to identify causality. By this definition, X causes Y, given an information set A_t, which includes at least (X_t , Y_t), if Y_t can be predicted better by using past X_t than by not using it.

Let $A_t = \{ A_s \mid s \leqslant t - 1 \}$ denotes the information set which includes A_s for all past s up to and including t − 1. The following three definitions can be introduced:

1. X causes Y if $\sigma^2(Y_t \mid A_t) < \sigma^2 (Y_t \mid A_t - X_t)$, where $\sigma^2 (Y_t \mid A_t)$ is the variance of Y_t about the best predictor by A_t.
2. X causes Y instantaneously if $\sigma^2 (Y_t \mid A_t, X_t) < \sigma^2 (Y_t \mid A_t)$.
3. Feedback exists between X and Y if X causes Y and Y causes X.

In order to define causality in a bivariate time-series model involving X_t and Y_t we make two simplifying assumptions. *First*, the set A includes X_t and Y_t only, and not a third variable. *Second*, there exist transformations T_x and T_y such that $x_t = T_x X_t$ and $y_t = T_y Y_t$ are a pair of linear, covariance-stationary time series not including any deterministic components, and that x_t and y_t preserve the causality relationship of X_t and Y_t.

Granger tests of causality therefore between GNP and EC can be performed via the following set of regressions:

$$\text{GNP} = f(\text{m past GNP, k past EC}) \quad (1)$$
$$\text{GNP} = f(\text{m past GNP}) \quad (2)$$
$$\text{EC} = f(\text{m past EC, k past GNP}) \quad (3)$$
$$\text{EC} = f(\text{m past EC}) \quad (4)$$

I use the quasi first-difference transformation and assume m = k = 4 in the lag structure, since it gives the best statistical results.

An alternative way of testing the direction of causation is proposed by Sims (1972). According to Sims' the test for unidirectional causality between X and Y is to regress Y on past and future values of X, taking account by generalized least squares or prefiltering of the serial correlation in w(t). Then if causality runs from X to Y only, future values of X in the regression should have coefficients insignificantly different from zero as a group.

To test via Sims' technique the causality between GNP and EC, the following four regression equations are formulated:

$$GNP = f\,(EC,\ m \text{ past lags and } k \text{ future lags of } EC) \qquad (5)$$

$$GNP = f\,(EC,\ m \text{ past lags of } EC) \qquad (6)$$

$$EC = f\,(GNP,\ m \text{ past lags and } k \text{ future lags of } GNP) \qquad (7)$$

$$EC = f\,(GNP,\ m \text{ past lags of } GNP) \qquad (8)$$

Equations (5) and (7) are in unrestricted forms; equations (6) and (8) are in restricted form. F statistics are calculated to test whether the coefficients of future values can be zero as a whole. Note that

$$F\,(df_1, df_2) = \frac{(RRSS\text{-}URSS)\ /\ df_1}{URSS\ /\ df_2}$$

where df_1 is the difference of the degree of freedom of the restricted regression and that of the unrestricted regression and df_2 is the degree of freedom of the unrestricted regression. RRSS is the residual sum of squares of the restricted regression and URSS is the residual sum of squares of the unrestricted regression respectively.

To alleviate the problem of time-series autocorrelation, all the regressions are transformed into quasi first-difference form. Since both Kraft and Kraft and Akarca and Long employed a lag structure of 3 past and 4 future in the right-hand side of the regressions, I adopt, for purpose of comparison, the same lag scheme. A constant term, current, 3 past and 4 future lags of the independent variables are specified on the right-hand side of the unrestricted regressions for testing of causality.

Results and Analysis

Before presenting the results, a word about data is in order. The annual data for the sample period of 1960-1983 is from the Central Bureau of Statistics of Indonesia. The nominal GDP in the Indonesian currency (rupiah) was transformed into constant GDP in 1973 prices. While energy consumption data is in physical units (BOEs). In conducting the tests, the variables were transformed into first-difference form to alleviate the problem of autocorrelation.

The results obtained from Sims' test are presented in Table 1. It is notable that the F statistics are insignificant for both equations relating GDP to energy consumption and vice versa. I infer that there appears to be no causal relationship between energy and GDP.

The results obtained from Granger's test are presented in Table 2. It is also notable that F statistics are insignificant for both equations. These results support the Sims' results, that is, no causal relationship between energy and GDP.

Table 1. **Causality between energy and GDP: Sims test**

Regression	F^a	Degree of freedom	Type	R^2	D-W
GDP = f(EC)	1.734	(3,12)	Unrestricted Restricted	0.67 0.53	1.53 1.22
EC = f (GDP)	0.50	(3,12)	Unrestricted Restricted	0.50 0.44	1.73 1.69

[a]Critical F(3,12) value at 5% level = 3.49

Table 2. **Causality between energy and GDP: Granger's test**

Regression	F^a	Degree of freedom	Type	R^2	D-W
GDP = f(EC)	0.66	(2,12)	Unrestricted Restricted	0.65 0.61	0.67 0.68
EC = f (GDP)	5.53	(2,12)	Unrestricted Restricted	0.60 0.23	1.83 1.59

[a]Critical F(2,12) value at 1% level = 6.93

Chow procedures are utilized to test the equality of the regressions fitted to 1960-1972 and 1973-1983 periods. I utilize Chow tests to determine possible structural change during the year 1973 because of the oil crisis.

Chow test procedure can be done in the following way: Suppose that we have two independent sets of data with samples sizes n1 and n2, respectively. The regression equation is:

$$y = \alpha_1 + \beta_{11} x_1 + \beta_{12} x_2 + \ldots + \beta_{1k} x_k + \mu \quad \text{for the first set}$$

$$y = \alpha_2 + \beta_{21} x_1 + \beta_{22} x_2 + \ldots + \beta_{2k} x_k + \mu \quad \text{for the second set}$$

For the β's the first subscript denotes the data set and the second subscript denotes the variable. A test for stability of the parameters between the populations that generated the two data sets is a test of the hypothesis:

$$Ho: \alpha_{11} = \beta_{12},\ \beta_{12} = \beta_{22},\ \beta_{1k} = \beta_{2k},\ \alpha_1 = \alpha_2$$

If the hypothesis is true, we can estimate a single eqvation for the data set obtained by pooling the two data sets.

The results of the Chow test, summarized in Table 3, indicate that there is no significant structural shift, which occurred around 1973.

Table 3. **Chow test: GDP = f(EC)**

Period	SSR	R^2	D-W	F(2,22)[a]
1960-1972	756,761.3	0.90	1.39	0.57
1973-1983	796,213.6	0.98	0.88	

[a]Critical F(2,22) value at 5% level = 3.40

Some Econometric and Economic Interpretations

The empirical results clearly indicate a strong statistical relationship between GDP and energy consumption in Indonesia. That there was a significant correlation between the two variables is evident from the high R^2 reported in Table 1 and Table 2. However, the causality tests reveal no unidirectional causal linkage between GDP and energy. Intuitively, energy should be correlated with GDP. However, causal relationship between energy and GDP are not self-evident and warrant rigorous investigation.

Several techniques are available to ascertain patterns of causality among economic variables. Regression analysis and spectral analysis have been used, for example, to assess the major determinant of common stock prices. Procedures to test causality were originally developed by Strotz and Wold (1960), they proposed that a diagonal covariance matrix could be recursive and causal. Baseman (1965) designed a statistical test of explicit causal chains. Sims (1980) provided operational interpretations of Granger (1969) causal orderings associated with exogeneity.

The techniques proposed by Sims and Granger delineated above are efficient methods for testing causality, in an ordering sense, between any pair of time series.

Since the main purpose of this paper is to produce empirical evidence regarding the causal relationship between energy and GDP, thus energy was regressed on GDP only. In a broader framework, one may, of course, posit that energy is a function of GDP, energy price and other relevant variables. In such a model, tests for causality can be done for the dependent variable, i.e. energy, and any one of its determinants. Essentially, four regressions are required for each of the determinants of energy. They are (1) regress energy on current and lagged values of the selected determinant; (2) regress energy on current, lagged and future values of determinants; regressions (3) and (4) are identical to (1) and (2), except the determinant becomes the dependent variable and energy becomes the independent variable.

The recent time-series study on the determinants of common stock prices by Kraft and Kraft (1977) and the analysis by Ortmeyer (1980) on the causal relationship between income and saving constitute two excellent examples of the application of Sims and Granger techniques to test causality in a multivariable framework.

Berndt and Wood (1979) and Griffin (1981) investigated the issue of gross and net complementarity between energy and capital. An aggregate production function relating GNP (Y) to energy (E), capital (K), labor (L) and material (M) is specified as follows: Y = F (E,K,L,M). Assuming weak separability of E, K and L vis- a-vis materials, the production function may be further expressed as Y = F (V,M) where V = v (E,K,L). In this formulation, energy as a practical matter is hypothesized, along with capital and labor, as a major input in the production process.

The hypothesized production function itself and even the strong statistical correlations obtained are, however, inadequate to indicate a unidirectional causal relationship. The causal linkage between GDP and energy is not self-evident, and our empirical analysis actually suggests no such non-spurious causal linkage for Indonesia. The results are extremely sensitive to samples, both in terms of sample length and the period of the data.

Conclusions

(1) There is a low-efficiency of energy use in Indonesia indicated by the increase of energy consumption which is caused more by energy intensity than by economic growth. This low-efficiency is also shown by the decreasing GDP-energy ratio.

(2) The tests indicate the presence of a strong relationship between GDP and energy consumption in Indonesia. However, applying Sims' and Granger' tests of causality to data sample, I only find a unindirectional flow from GDP to energy consumption and no causal relationship between GDP and energy consumption in Indonesia. However, the tests indicate the presence of a strong statistical relationship between GDP and energy consumption in Indonesia. Therefore, while the level of economic activity may influence the energy consumption, the level of energy consumption has no causal influence on economic activity. This indicates that there is a possibility to reduce energy requirements (energy saving) of producing a given quantity of GDP without raising the use of other inputs. It implies that an energy conservation program is a feasible policy tool to make the Indonesian economy more competitive by reducing production costs.

(3) Based on (1) and (2), an increased efficiency of energy use will not reduce the GDP. The efficiency of energy use in Indonesia therefore has to be increased in order to conserve energy sources in the future. A policy that stimulates economic actors (producers and consumers) to use energy efficiently is really needed; such as, an appropriate energy pricing

policy which would affect the pattern of energy consumption and production process in the Indonesian economy.

(4) The analysis above is a macro point of view by using aggregative measures which often have many problems. The change of such energy consumption in this paper only concerns about the commercial energy and does not account for non-commercial energy that is widely being used, especially in rural area.

References

Akarca, A. T. and T. V. Long (1980), "On the Relationship Between Energy and GNP: A Reexamination," *The Journal of Energy and Development*, Spring.

________ (1979), *Energy and Employment: A Time Series Analysis of the Causal Relationship*, Resources and Energy, Vol. 2.

Allen, E. L.(1976), *US Energy and Economic Growth, 1975-2010*, Institute for Energy Analysis, Report ORAU/IEA 76-7.

Berndt, E. and D. O. Wood (1974), "An Economic Interpretation of the Energy-GNP Ratio," in *Energy: Demand, Conservation, and Institutional Problems*, ed. S. Macrakis, Cambridge, MIT Press.

Bohi, Douglas R.(1981), *Analyzing Demand Behavior: A Study of Energy Elasticities*, The John Hopkins University Press, Baltimore, Maryland.

Chow, Gregory C. (1960), "Tests of Equality between Sets of Coefficients in Two Linear Regressions," *Econometrica, Vol. 28, pp. 591-605,* July.

Elias, J. and V. Grabik (1980), "A Comparison of Energy Consumption in Eastern and Western Europe," *Energy Economics*, October.

Erol, U. and E. S. H. Yu(1987), "Time Series Analysis of the Causal Relationships Between U.S. Energy and Employment," *Resources and Energy*, Vol. 9.

Granger, C. W. J.(1969), "Investigating Causal Relations by Econometric Model and Cross-Spectral Methods," *Econometrica*, July.

Granger, C. W. J.(1964), *Spectral Analysis of Economic Time Series*, Princeton University Press, New Jersey.

Hitch, C. J. (1978), *Energy Conservation and Economic Growth*, American Association for the Advancement of Science, Selected Symposium 22.

Hogan, W. W. and A. S. Manne (1977), "Energy-Economy Inter actions: The Fable of the Elephant and the Rabbit," in *Modeling Energy-Economy Interactions: Five Approaches*, ed. C.H. Hitch, Resources for the Future, Washington, D.C.

Khazzoom, J. D. (1976), *Proceedings of the Workshop on Modeling the Interrelationships Between the Energy Sector and the General Economy*, Special Report 45, Electric Power Research Institute, Palo Alto.

Kraft, J. and A. Kraft (1978), "On the Relationship Between Energy and GNP," *The Journal of Energy and Development*, Spring.

Leach, G. (et.al) eds. (1986), *Energy and Growth: A Comparison of 13 Industrial and Developing Countries,* Butterworths Scientific, England.

Long, T. V. and L. Schipper (1978), "Study Series on US Economic Growth from 1875 to 1985: Prospects, Problems and Patterns," US GPO, Washington, DC, 1976, with a modified version published in *Energy,* March.

Moroney, J. R., "Ouput and Energy: An International Analysis," *The Energy Journal,* Vol. 10, No. 3.

Nordhaus, William D., *International Studies of the Demand for Energy,* North-Holland Publishing Company, 1977.

Pierce, D. A. and L. D. Haugh (1977), "Causality in Temporal Systems," *Journal of Econometrics,* 5.

Sims, C. A. (1972), "Money, Income, and Causality," *American Economic Review,* September.

Sims, C. A. (1980), "Macroeconomics and Reality", *Econometrica.*

Soesastro, Hadi (1985), *Peranan Energi dalam Pertumbuhan Ekonomi,* Analisa, Centre for Strategic and International Studies, Jakarta.

Verleger, P. K. (1974), *"The Relationship between Energy Demand and Economic Activity"*, in *Energy: Demand, Conservation, and Institutional Problems,* ed. S. Macrakis, Cambridge, MIT Press.

_______ (1973), *"An Econometric Analysis of the Relationship Between Macro Economic Activity and U.S. Energy Consumption,"* in *Energy Modeling, Art, Science, and Practice,* ed. M. Searl, Resources for The Future, Washington, D.C.

Yu, Eden S. H. and B. K. Hwang (1984), *"The Relationship Between Energy and GNP: Further Results,"* Energy Economics, July.

Yu, Eden S. H. and J. Y. Choi (1985), *"The Causal Relationship Between Energy and GNP: An International Comparison,"* The Journal of Energy and Development, Vol. 10.

Zilberfarb, B. and F. G. Adams (1981), *"The Energy-GDP Relation ship in Developing Countries,"* Energy Economics, October.